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COMMENTS ON THE TEMPERATURE COEFFICIENT OF RESISTANCE AS USED IN WIRE BRIDGE ELECTRO-EXPLOSIVE DEVICE ANALYSIS (U)

1 NOVEMBER 1961

NOL

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

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COMMENTS ON THE TEMPERATURE COEFFICIENT OF RESISTANCE AS USED IN WIRE BRIDGE ELECTRO-EXPLOSIVE DEVICE ANALYSES

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ABSTRACT: The resistance of an electro-explosive device (EED) at some temperature elevation, θ, above ambient can be expressed by $R = R_0 (1 + \alpha\theta)$, where R_0 is the resistance at ambient temperature, and α is the temperature coefficient of resistance. This equation is not consistent with the handbook definitions of temperature resistance coefficient wherein the parameters R_0 and α are referenced to $0^{\circ}C$ conditions rather than ambient temperature conditions. Misuse of the numerical values can lead in some cases to significant computational errors. The source, magnitude, and correction of these errors is presented. Also the mathematical basis for an efficient test plan for the determination of α, R_0, and γ is given.

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As part of the Naval Ordnance Laboratory's effort on the HERO (Hazards of Electromagnetic Radiation to Ordnance) program an electro-thermal model has been postulated to explain the response of electro-explosive devices to various electrical environments. Mathematical implementation of this model requires the use of an equation relating the resistance of the EED bridgewire to its temperature. Misunderstanding of the detail of this resistance-temperature relationship has been all too often encountered. It is the purpose of the present report to explain the sources of confusion and thereby eliminate the errors resulting therefrom.

This work was carried out under Task NOL-443, Guided Missile Propulsion Systems, Hazards of Electromagnetic Radiation to Ordnance (HERO). It should be of interest not only to the overall HERO program of the Navy but also to the field of electrical measurements in general.

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INTRODUCTION

1. Much work has been devoted to the application of a lumped-parameter electro-thermal model* to the study of the nature of wire bridge electro-explosive devices (EEDs). The work has led to a more fundamental understanding of their transducing action (electrical signal in--explosive action out) and has aided in the solution of a number of rather diverse problems.

2. The experimental approach toward verification and use of this model has required measurement of the bridgewire temperature elevation, θ, under various conditions of time, temperature, energy and power environment, and history. The verification was accomplished by utilizing the resistance-temperature property of the bridgewire--i.e., the bridgewire was used as its own resistance thermometer. This property is expressed by the simple linear relationship,

$$R = R_o (1 + \alpha\theta), \qquad (1)$$

where R_o is the initial resistance (at ambient temperature),
α is the temperature coefficient of resistance, and
θ is the temperature elevation above ambient.

Equation (1) is used in the derivation of a large number of equations describing specific EED properties.

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*

$$C_p \frac{d\theta}{dt} + \gamma\theta = P(t)$$

where C_p is the thermal heat capacity of the bridge

θ is the bridgewire temperature elevation above ambient

γ is the heat loss factor

$P(t)$ is the power-time function.

3. Equation (1) is of the same form as is used in the handbook definition of temperature-coefficient-of-resistance.

$$R = R_0 \left[1 + \alpha (T - T_0) \right] \tag{2}$$

where

α is "the ratio of the change in resistance in a wire due to a change of temperature of 1^oC to its resistance at 0^oC".

Because T_0, the base temperature, is usually taken at 0^oC, the above equation is often written

$$R = R_0 (1 + \alpha T)$$

which, though not the same, is easily confused with Equation (1).

4. Apparently, it is too easily forgotten that a specific value of α for a given material is meaningful only when consistent with the base (reference) temperature. Within the ordinary temperature limits Equation (1) describes the resistance-temperature relationship as a linear function. Occasionally the notion is encountered that α is the slope of the resistance-temperature curve so that a specific numerical value of this slope will be independent of the temperature. The slope of the linear equation is, of course, the product αR_0. Since the product is independent of temperature while the resistance, R_0, will vary as a function of the temperature at which it is determined, it can be seen that α will have a reciprocal relationship to R_0.

5. Thus, it can be seen that the values of α and R_0 in a specific system depend upon T_0, the temperature upon which they are based. As a consequence, numerical solutions of the various electro-thermal equations will be in error unless the values of R_0 and α are handled properly. The purpose of this report is to explain the differences and similarities between Equations (1) and (2), to show how the parameters should be corrected for differences in base temperatures, and to estimate the magnitude of errors that might arise from failure to correct for the difference.

MATHEMATICAL EXPOSITION

6. Ordinarily, handbook values of α are given for a base temperature of 0^oC. The general Equation (2) can be rewritten for this specific base temperature

$$R = \hat{R}_0 \left[1 + \hat{\alpha} T\right] \tag{3}$$

where $\hat{R}_0$ is the resistance at 0°C, and

$\hat{\alpha}$ is the temperature coefficient of resistance at 0°C.

7. In order to reserve α for the general equation (which visibly incorporates the base temperature) and also to denote that Equation (1) uses the ambient temperature as the base temperature, Equation (1) is rewritten

$$R = R_a \left[1 + A\Theta\right] = R_a \left[1 + A (T - T_a)\right] . \tag{4}$$

where R_a is the resistance at ambient temperature (rather than R)

T_a is the ambient temperature (in °C),

A is the corresponding coefficient of resistance,

and $T = \Theta + T_a$.

8. Since the individual values of α and R_0 for a group of EEDs will ordinarily be given for a base temperature other than ambient, it will be necessary to compute R_a and A for use in the electro-thermal equations. From Equation (2) it can be seen that

$$R_a = R_0 (1 + \alpha T_a - \alpha T_0). \tag{5}$$

Equation (4) can then be rewritten and set equal to Equation (2):

$$R_0 \left[1 + \alpha T - \alpha T_0\right] = R_0 \left[1 + \alpha T_a - \alpha T_0\right]\left[1 + AT - AT_a\right] .$$

From this

$$A = \frac{\alpha}{1 + \alpha T_a - \alpha T_0} . \tag{6}$$

9. When the base temperature for particular α and R_0 data is the usual value, i.e., when $T_0 = 0$°C, then Equations (5) and (6) reduce to:

$$R_a = \hat{R}_0 (1 + \hat{\alpha} T_a), \tag{7}$$

and

$$A = \frac{\hat{\alpha}}{1 + \hat{\alpha} T_a} . \tag{8}$$

ASSESSMENT OF ERRORS

10. Error in Resistance at Elevated Temperature, Type 1.

The usual situation is as follows:

R_0 is interpreted to be the initial resistance as it is measured at ambient temperature (R_a) [consistant]

α is used as tabulated at some base temperature and not corrected. [inconsistant]

θ is interpreted as $T-T_a$. [consistant]

Table 1

Type 1. Errors in Estimate of Resistance at Elevated Temperatures (Due to Improper Use of Coefficient of Resistance)

α $\frac{\text{ohm}}{\text{ohm }^{\circ}\text{C}}$	T, Elevated Temperature ($^{\circ}$C)			
	70	120	200	520
0.00075	0.06%	0.10%	0.20%	0.41%
0.001	0.10%	0.18%	0.33%	0.67%
0.002	0.36%	0.67%	1.14%	2.00%
0.003	0.78%	1.38%	2.25%	3.60%
0.004	1.33%	2.29%	3.56%	5.33%

$T_a = 20^{\circ}C$

$T_0 = 0^{\circ}C$

The actual equation used is

$$R = R_a \left[1 + \alpha (T - T_a) \right] .$$

The equation that should be used is either

$$R = R_0 \left[1 + \alpha(T - T_0)\right]$$

or

$$R = R_a \left[1 + A\,(T - T_a)\right] .$$

The error equation is

$$E = 100 \left[\frac{\text{Actual-True}}{\text{True}}\right] = 100 \ \frac{\text{Actual}}{\text{True}} - 100$$

$$= 100 \ \frac{R_a \left[1 + \alpha(T - T_a)\right]}{R_a \left[1 + A\,(T - T_a)\right]} - 100$$

which, upon substitution of Equation (6) for A, becomes

$$E = \frac{100\ \alpha^2\ (T_a - T_0)\ (T - T_a)}{1 + \alpha\,(T - T_0)} .$$

This function has been evaluated (Table 1) for various typical values of α and T assuming $T_a = 20^oC$ and $T_0 = 0^oC$.

11. Error in Resistance at Elevated Temperature, Type 2.

For the situation where R_0 and α values, measured at base temperature T_0, are both used as if the base temperature had been T_a, the actual equation used is:

$$R = R_0 \left[1 + \alpha(T - T_a)\right]$$

when

$$R = R_0 \left[1 + \alpha(T - T_0)\right]$$

should have been used.

Table 2

Type 2. Errors in Estimate of Resistance at Elevated Temperatures (Due to Improper Use of Coefficient of Resistance and Initial Resistance)

α $\frac{\text{ohm}}{\text{ohm}\ ^{\circ}\text{C}}$	T, Elevated Temperature ($^{\circ}$C)				
	0	20	80	140	300
0.0005	-1.01%	-1.00%	-0.98%	-0.94%	-0.88%
0.001	-2.04%	-2.00%	-1.92%	-1.79%	-1.56%
0.002	-4.17%	-4.00%	-3.70%	-3.23%	-2.56%
0.004	-8.70%	-8.00%	-6.90%	-5.40%	-3.77%

$T_a = 20^{\circ}C$

$T_o = 0^{\circ}C$

The error equation in this case is

$$E = 100 \; \frac{R_o\left[1 + \alpha(T - T_a)\right] \; - \; R_o\left[1 + \alpha(T - T_o)\right]}{R_o\left[1 + \alpha(T - T_o)\right]} \; - 100$$

$$= \frac{100\,\alpha(T_o - T_a)}{1 + \alpha(T - T_o)} \; .$$

The magnitudes of the errors have been evaluated (Table 2) assuming $T_a = 20^{\circ}C$ and $T_o = 0^{\circ}C$.

12. <u>Error in Coefficient Due to Misinterpretation of Base Temperature.</u> (α used when A should have been used):

The error equation is

$$E = 100\left[\frac{\text{Actual} - \text{True}}{\text{True}}\right] = 100\left[\frac{\alpha - A}{A}\right]$$

which upon substitution of Equation (6) for A becomes

$$E = 100 \alpha \left[T_a - T_o \right] .$$

Thus it can be seen that, for the case where $T_a = 20^{\circ}C$, and $T_0 = 0^{\circ}C$, the error in the value of the coefficient will be + 1.0%, + 2.0%, + 4.0%, and + 8.0% for values of α correspondingly of 0.0005, 0.001, 0.002, and 0.004 ohms/ohm/°C.

DETERMINATION OF α , γ , AND R_0 FOR AN EED BY THE THREE POINT METHOD

13. Measurements Required. Specific instrumentation for making the following determinations is not spelled out. Numerous equivalent methods are available. There are, of course, a number of instruments, peculiarly suited for this work which have been reported in references (1), (2), and (3).

a. Determine the resistance at ambient temperature with negligible current through the bridge*. This is the resistance R_a.

b. For a current I through the bridgewire, measure the stabilized resistance R_e that the bridgewire attains at equilibrium.

c. Find a temperature T_e for which the bridgewire resistance reaches the same value R_e obtained in step b.

14. Derivation. From the above measurements, the values for R_a, T_a, R_e, and T_e, are available. Substituting these values into

$$R_e = R_a \left[1 + A \left(T_e - T_a \right) \right]$$

gives sufficient information to compute A, R_0 , α , $\hat{R}_o$, and $\hat{\alpha}$.

$$A = \frac{R_e - R_a}{R_a \left(T_e - T_a \right)}$$

$$R_0 = \frac{R_a \left(T_e - T_o \right) - R_e \left(T_a - T_o \right)}{T_e - T_a}$$

*By negligible is meant a current low enough so that the elevation of the bridgewire from heating by this current flow is small compared to the elevation to T_e (see step c).

$$\alpha = \frac{R_e - R_a}{R_a (T_e - T_o) - R_e (T_a - T_o)}$$

$$\hat{R}_o = \frac{R_a T_e - R_e T_a}{T_e - T_a}$$

$$\hat{\alpha} = \frac{R_e - R_a}{R_a T_e - R_e T_a}$$

Furthermore, since the heating current, I, was determined in step b, the power to raise the bridgewire to T_e can be computed as I^2R_e. Under steady state (constant power) conditions the equation for the thermal model (see footnote to paragraph (1)) can be solved:

$$\gamma \theta = P(t).$$

Therefore γ can be computed from experimental data by:

$$\gamma = \frac{I^2R_e}{\theta} = \frac{I^2R_e}{T_e - T_a} .$$

CONCLUSIONS

14. It can be seen that in many practical situations the improper choice of base temperature for either or both parameters will introduce negligible errors. Other situations (for instance with Tungsten whose α is about 0.003 ohms/ohm/^{o}C) the error may be significant. In any case it is simple to make the proper choice of parameter and to correct available data consistent with the choice.

15. The three-point method for determining α , γ , and R_0 has been used to make many hundreds of sets of determinations. It is an efficient method and capable of accuracy in the order of 1% or better, depending, of course, upon the quality of the instrumentation.

REFERENCES

(1) L. A. Rosenthal, "Electrothermal Equations for EEDs", NavOrd Report 6684, 15 Aug 1959.

(2) L. A. Rosenthal, "The Harmonic Generation Technique for the Determination of Thermal Characteristics of Wire-Bridge EEDs", NavOrd Report 6691, 9 Sep 1959.

(3) L. A. Rosenthal, "Cooling Curve Generator and its Application to EEDs", NavWeps Report 7313, 15 Dec 1960.

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2. Electro-explosive devices - Temperatures
3. Wire, Bridge

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I. Title
II. Ayres, James N.
III. Project

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 61-154)
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